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RESULTS OF GENERAL SURVEY OF TOKYO BAY (A 1971 JOINT SURVEY COVERING THE TOKYO METROPOLIS AND CHIBA AND KANAGAWA PREFECTURES)

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RESULTS OF GENERAL SURVEY OF TOKYO BAY
(A 1971 Joint Survey Covering the Tokyo Metropolis and Chiba and Kanagawa Prefectures)

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1. Introduction

It is said that the Pollution of Tokyo Bay has increased in recent years, with the reddish brown tide fast becoming an ever-present phenomenon.

Environmental quality standard guidelines for Tokyo Bay were promulgated in May, 1971 and, although work on a plan to purify the area is being rushed through, until now no overall survey had been carried out and consequently the actual situation was not clearly understood.

With the ultimate aim of clarifying the pollution situation as affecting the Tokyo metropolis and the two prefectures, a joint survey was begun in 1971. In the first year, a survey was carried out to cover many aspects of the problem in order to obtain an overall picture of the present pollution situation and to provide basic materials for later surveys and pollution countermeasures. The purpose of this paper is to outline the nature of the survey and the results obtained.

In this investigative research, the authors received the able guidance of Mr. Shoichi Nambu, head of the Health Technology Division of the Institute of Public Health and the cooperation of Drs. Yoshio Ide and Hiroshi Fukushima in life form identification.

2. Outline of the Survey

Some 72 locations, at intervals of 4 *km* were decided upon, and in October at all of them, and in May, August and February at 15 of these points, surveys covering water quality, organisms and sea bed sediments were carried out.

In addition, core samplings were taken at five places, bay mouth tide currents and the intake of pollutants from the five big rivers checked, the resulting flow and diffusion data statistically analyzed.

Items for which measurements were taken:

(Water quality)

Water temperature, transparency, water color, pH, dissolved oxygen, chlorinity, chemical oxygen demand (COD), biochemical oxygen demand

(BOD), ammonium-ions, nitrites, nitrates, organic nitrogen, phosphates, n-Hexane extracts, suspended solids and eight items*related to health listed in the environmental quality standards.

(Sediments)

Mud temperature, odor, appearance, specific gravity, composition, water content, pH, chemical oxygen demand (COD), ignition loss, sulfides, heavy metals and the eight items related to health.

(Organisms)

Phytoplankton, zooplankton, benthos and sulfate-reducing bacteria.

3. Results

(1) Water Quality

Transparency: Offshore water transparency in Tokyo Bay is poor the year round and particularly in May its reading dropped to below one meter. As for the four seasonal results, May was the worst month for the entire area with readings below two meters. Transparency was generally around 3 meters in the February cycle with a maximum reading of 5.3 meters in one place, but this was the highest for the entire year. In reports covering May, readings for the entire bay in May from 1955 onwards [1] have varied little from 1965 to the present time.

Dissolved oxygen: From the bay mouth to Nakanose in October the degree of oxygen saturation of surface water was over 100% but, the farther into the bay readings were taken, the lower the percentage was found to be; and it was down close to 50% immediately offshore of the Port of Tokyo. On the other hand, the amount of dissolved oxygen in the water immediately above the sea bed was about 80–95% for almost the entire area in the winter (vertical circulation) cycle, as measured in February. In the summer (vertical stratification) period measured in August, the level in the northern half of the bay dropped to generally less than 20% and in October it is under 75% in the northern half; and under 50% west of a line between Kawasaki and Funabashi, thus showing marked oxygen saturation characteristics for each water basin.

Nutritive salts: Since the change in the amount of inorganic nutritive salts is closely related to the increase and decrease in the amount of phytoplankton, we shall now turn our attention to the total quantity of nitrogen, including that in organisms. **Figure 1** shows the picture for surface water in the winter circulation (February) period. It can be clearly seen that

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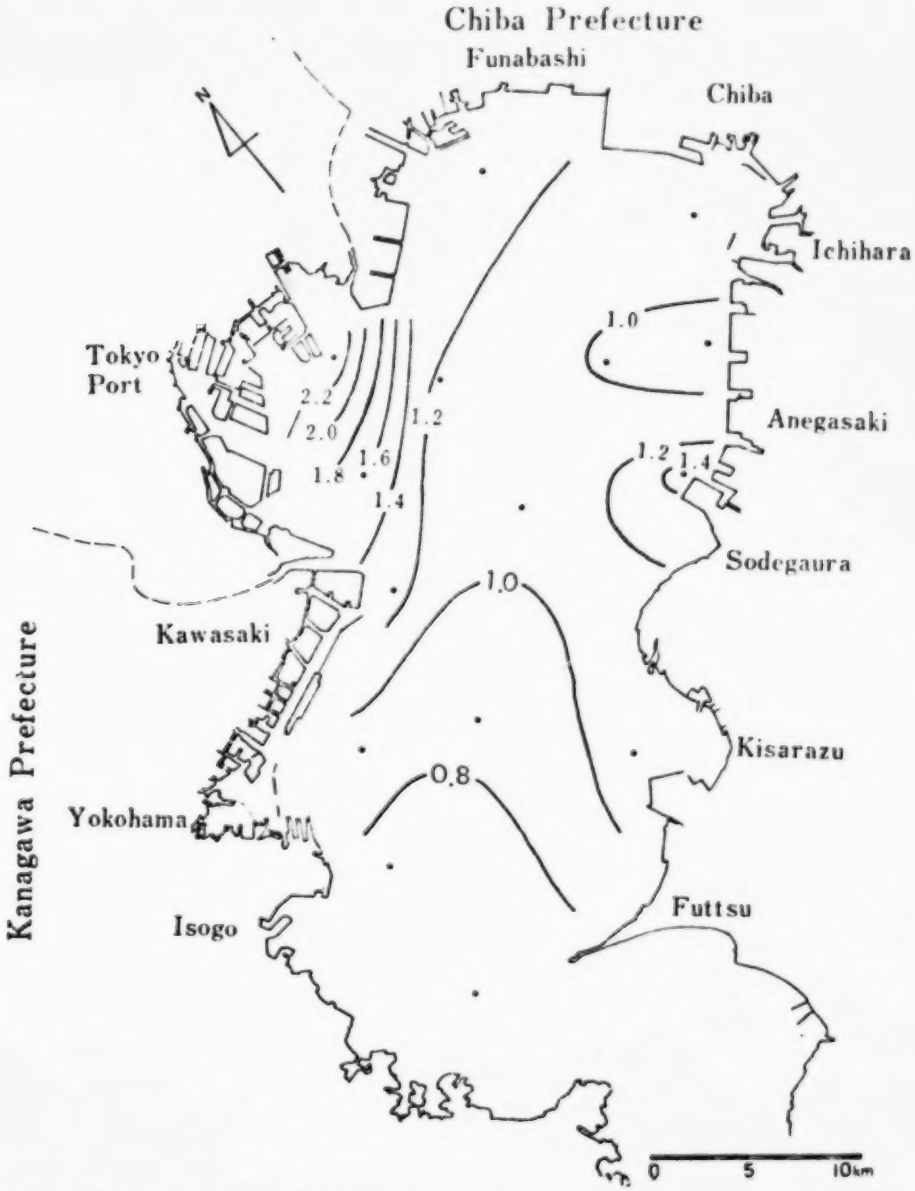
* Cynide, Alkyl-Hg, Organic P such as Parathion, Cd, Pb, Cr^{+6}, As and Total-Hg the items which were decided upon concerning health in the water quality environmental standards by the Cabinet on April 24, 1970.

Figure 1 Total Nitrogen of Surface Water in Tokyo Bay, Feb. 1972 (mg N/l)



north of a line between Yokohama and Futtsu the level is over 0.8 mg N/*l*, that is, eutrophic.

Figure 2 shows the distribution of phosphates for surface water in February. In over half the region the figure was over 0.03 mg P/*l*. According to the report by Hogetsu[2], there is over 0.1 mg P/*l* total phosphates

in the innermost part of the harbor. Judging from the distribution of nutrients, it appears that the big inflow which is doing the most to increase eutrophication of the waters of Tokyo Bay comes from the five rivers flowing through the wards of Tokyo into the bay.

Chemical Oxygen Demand: This varies considerably, according to the season, but by the alkali method it was found to be 1–3 mg O_2/l in the winter circulation period but close to 10 mg O_2/l in the summer stratification period; with an increasing trend toward high concentrations in the west and low concentrations in the east. **Figure 3** shows results for analysis by the acid process of surface water in October. It is seen that at 65% of the observation points the environmental standard was reached and in one third it was exceeded.

Even though the pollutants flowing into Tokyo Bay were tenatively equated with COD and diffusion calculations carried out (See later in report), diffusion to places far off shore could not be calculated even after a period of 45 days was experimentally entered into the calculations. This is an indication that the appearance of areas of high COD concentrations far off shore shows that there are considerable amounts of organic matter being produced by primary photosynthesis in photoplankton. According to Hogetsu's report[2], the sum of ~~carbon in~~ Carbon in hydrocarbons, proteins, and ~~carbon in~~ fats, has a linear relationship to the amount of chlorophyll, and makes up from 15 to 50% of the total of organic carbons. This amount is less than in the open sea.

The above facts and figures make it clear that the organic pollution of Tokyo Bay has been brought about by unusually high organism productivity resulting from the great inflow of nutrients and by the considerable influx of organic matter not directly related to living organisms such as chemical industry wastes, etc.

Other: Analyses were carried out at 68 points in October in connection with the eight items related to health in the environmental quality standards, but nothing was detected.

Transport of water and pollutants at the mouth of the bay

Table 1 lists the results of twelve-hour observations concerned with inflow and outflow at four points between Yokosuka and Futtsuzaki at the mouth of the bay.

The quantity of inflow and outflow showed a difference of around 10% but its reliability is not certain. The patterns of inflow and outflow of all components tends to be similar; flowing in the Futtsuzaki side and out on the Yokosuka side.

Numerical Analysis of Water Pollution

In order to obtain estimates of the amount of pollutants flowing into Tokyo Bay, its circumference was divided into 16 blocks and estimates

Figure 2 Phosphate of Surface Water in Tokyo Bay, Feb. 1972 (mg P/ℓ)

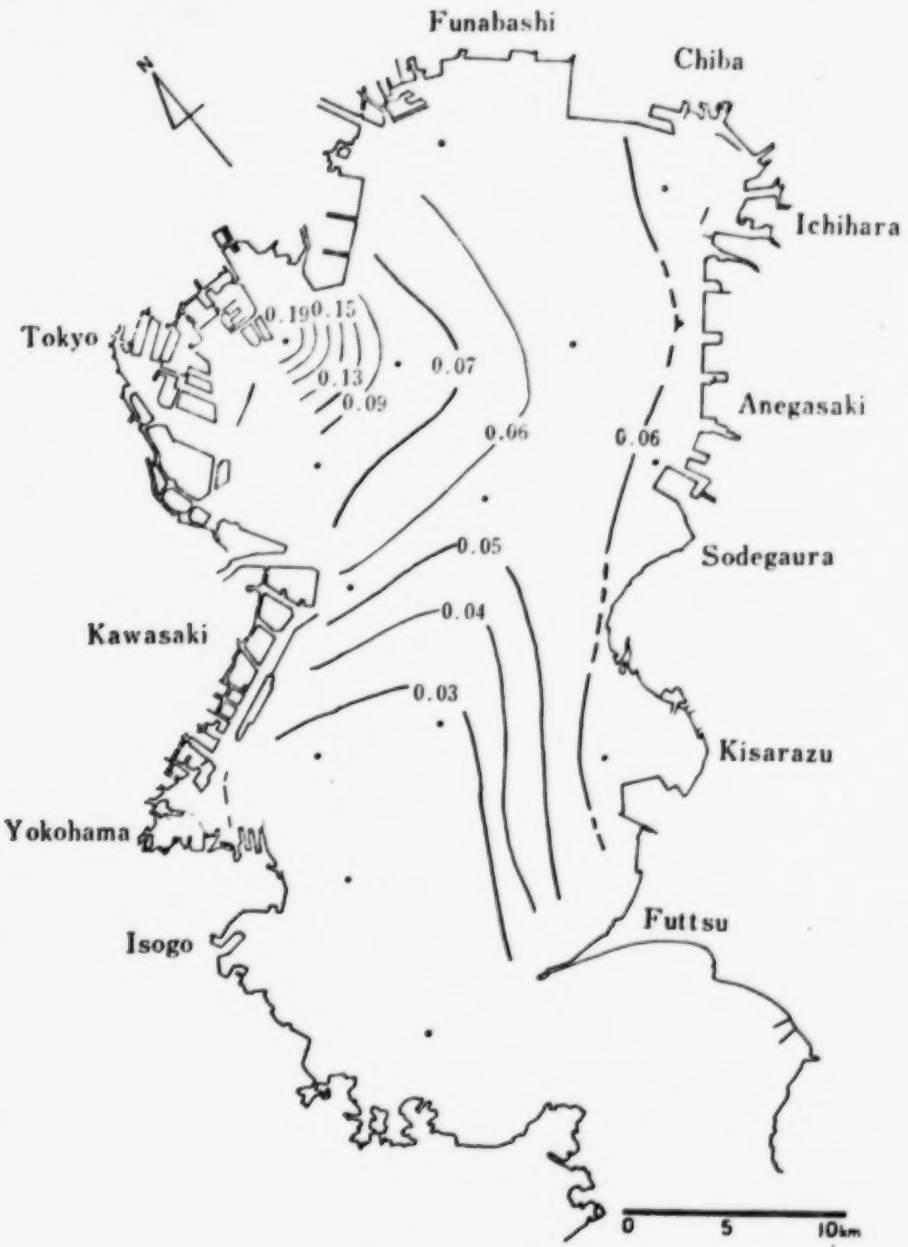


Figure 3 Chemical Oxygen Demand of Surface Water by the Acid Method in Tokyo Bay, Oct. 1971 (mg O_2/ℓ)

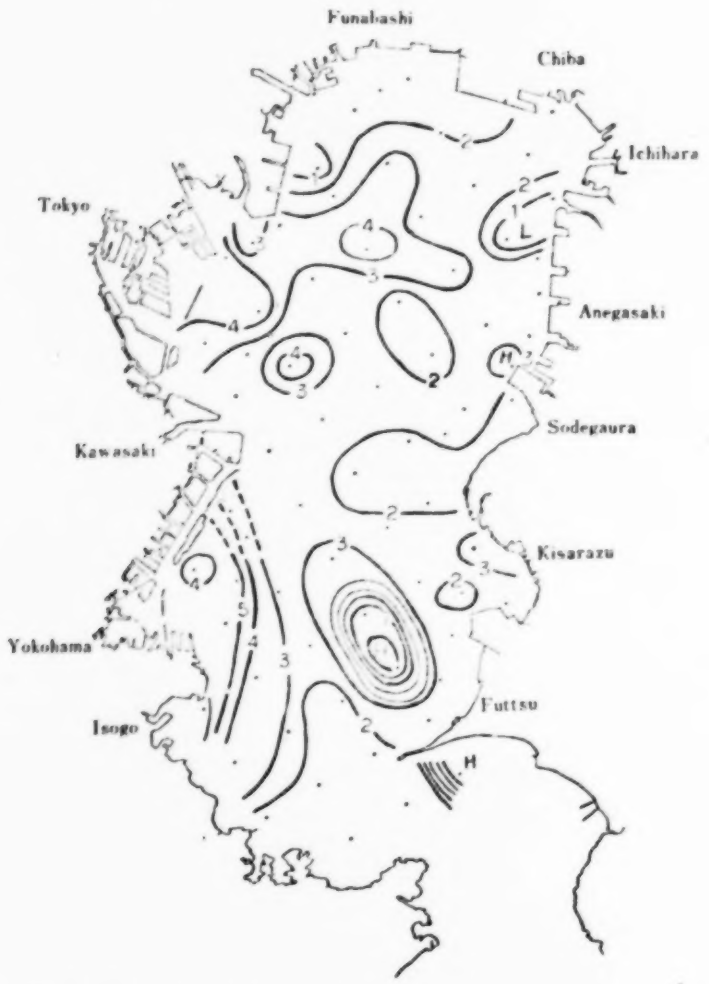


Table 1 Transportation of Water and Pollutants at the month of Tokyo Bay (12 hour total)

	Outflow	Inflow
Water volume	$13.20 \times 10^8 m^3$	$12.09 \times 10^8 m^3$
Fresh water volume (calculated from salinity)	$8.65 \times 10^7 m^3$	$7.79 \times 10^7 m^3$
BOD load	1,284 ton	1,038 ton
COD load (alkali method)	1,190 ton	931 ton
COD load (acid method)	2,236 ton	2,236 ton

made in terms of COD (acid process). Results showed that 106 tons per day from Chiba Prefecture, 475 tons per day from Tokyo and 558 tons per day from Kanagawa Prefecture – a total of about 1,100 tons in terms of COD per day. For purposes of calculation, Tokyo Bay was divided into a matrix of 2 *km* divisions each way. Tidal oscillation and fresh water inflow was added to determine the currents for each mesh of the matrix. The load of pollutants was then added to this. It was found that off Yokohama, as the tide comes in, a clockwise eddy is formed. The pollutant load was added to this and diffusion calculations for 79 tidal cycles results given in Figure 4 were made. Figures for the west are higher than for the east, a high region reaches toward the area offshore from Yokohama and is higher than figures obtained for the middle of the bay.

(2) Nature of the Sea Bed and Sediments

General items: There is sand around the coast of Tokyo Bay and mud on the sea bed offshore. The inner part of the bay from Chiba to the Kawasaki area is a region with an ignition loss of over 10%, excepting the Funabashi coastal area which is ~~more~~ less than 8%. The entire offshore area has a high content of organic substances.

Except for the area off Funabashi, the amount of potassium permanganate consumed (COD) is more than 10 mg O_2/g (dried mud). The amount of sulfides off Tokyo is great at 2 mg S/g (dried mud) and coincides with the trend in water quality.

Between Funabashi and Chiba and between Anegasaki and Futtsu the seabed is sand and, because the water is shallow for a long way out from the beach, there is considerable biooxidation, the figures obtained being close to normal but it can be said that all areas other than these are deteriorating. Since readings were not taken at many points on the Kanagawa Prefecture side, regional tendencies there have not been clarified, but, judging from the distribution of benthos, the situation off Yokohama and Kawasaki has deteriorated considerably.

Special items: Among the eight items concerned with health in connection with investigation of the sea bed, those showing the distribution of total mercury, lead, cadmium and chrome are to be found in Figure 5.

A look at the general picture shows some common concentration distribution patterns. There is a tendency for heavy concentrations to extend out from the Tokyo port area and along the western side of the bay to its mouth, higher concentrations being found than in the eastern and inner bay area, and this is attributed to the fact that whereas development of the Chiba side has taken place only in recent years, on the other side there is the big Tokyo metropolis and the Tokyo-Yokohama industrial belt which has been growing since the Meiji era.

Figure 4 The Pattern of Deffusion of COD by Numerical Experiment after 79 Tidals in Tokyo Bay (mg O_2/ℓ)

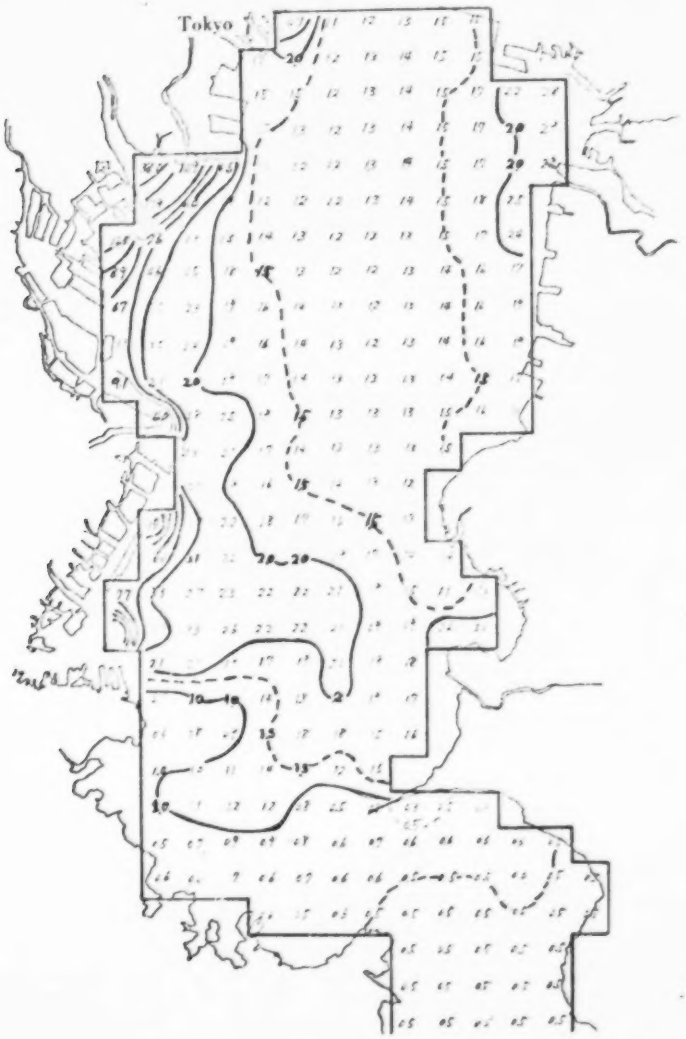


Table 2 The Volume of Total Plankton Settled with Formarin after Sampling (mℓ/10ℓ sea water)

Depth	0.5 m	5 m	1 m above bottom
May 1971	2.0 ~ 140	1.1 ~ 4.8	0.2 ~ 6.0
August 1971	0.6 ~ 6.0	0.2 ~ 2.0	0.3 ~ 1.5
October 1971	0.4 ~ 17.4	0.4 ~ 13.8	0.1 ~ 9.2
February 1972	0.9 ~ 4.6	1.2 ~ 4.2	0.5 ~ 6.6

Core sampling: In order to study the history of the sea bed 3–4 meter cores were taken at five places in the bay and a 20 cm long sections of mud were taken at one meter intervals and analyzed. Except for a few cases, high concentrations of heavy metals were found in upper strata, but the deeper down readings were taken the smaller the concentrations of heavy metals were. Readings for the bottom strata were close to the Clarke coefficient.

(3) Organisms

Phytoplankton: Figures for total plankton volume per 10 liters of water when sea water, without prior treatment, was fixed with formalin and allowed to settle are shown in **Table 2.** It can be seen from this table that the amount of plankton is greater in May than at any other time of the year and there is more toward the surface than in lower strata of water.

Seasonal classification of the dominant species in the precipitant shows that from summer into autumn Thalassiosira mala is the most common, in autumn Chlamidomonas sp., not in the least Skeletonema costatum as dominant with Chaeltoceras next, and in spring Skeletonema costatum is dominant, followed by Exuviaella marina and Chaeltoceras sp. In summer, off the Chiba Port coast Euglena sp. appears to be the most dominant species.

The total count of phytoplankton shows high counts off Kawasaki in May; in August lying north-south with the Nakanose vicinity as the mid-point; in October in batches between Tsurumi and Kisarazu and off Sodegaura and Anegasaki, and in February distribution was fairly even except for comparatively high counts in the Nakanose vicinity.

Zooplankton: A study of sample content when these samples were collected by drawing a net up vertically from about one meter above the sea bottom to the surface shows the greatest quantities in February; zooplankton including Chaeltoceras sp. etc., being the main constituents – 2 to 40 times as much as in other seasons. In February the deposit is greenish in color and it is light brown at other times.

As for seasonal variations, in zooplankton, the least complexity and smallest amount is found in May with Tintinnida predominant off Kawasaki and Yokohama and Cyclopoida off Tokyo and the Chiba Prefecture side. The picture is slightly more complex in August with Noctiluca predominating off the Chiba-Anegasaki coast and Cyclopoida elsewhere. From the bay mouth to the middle and from Kanagawa Prefecture, Microsetella was noticeable and in October at most points Cyclopoida was dominant with Microsetella next, also in considerable quantities. In February, Cyclopoida is dominant throughout, except for the area off Anegasaki where Microsetella is dominant. Although Calanoida is comparatively com-

Figure 5 Distributions of Heavy Metals in the Sediment in Tokyo Bay, Oct. 1971 (mg/kg-dry base)

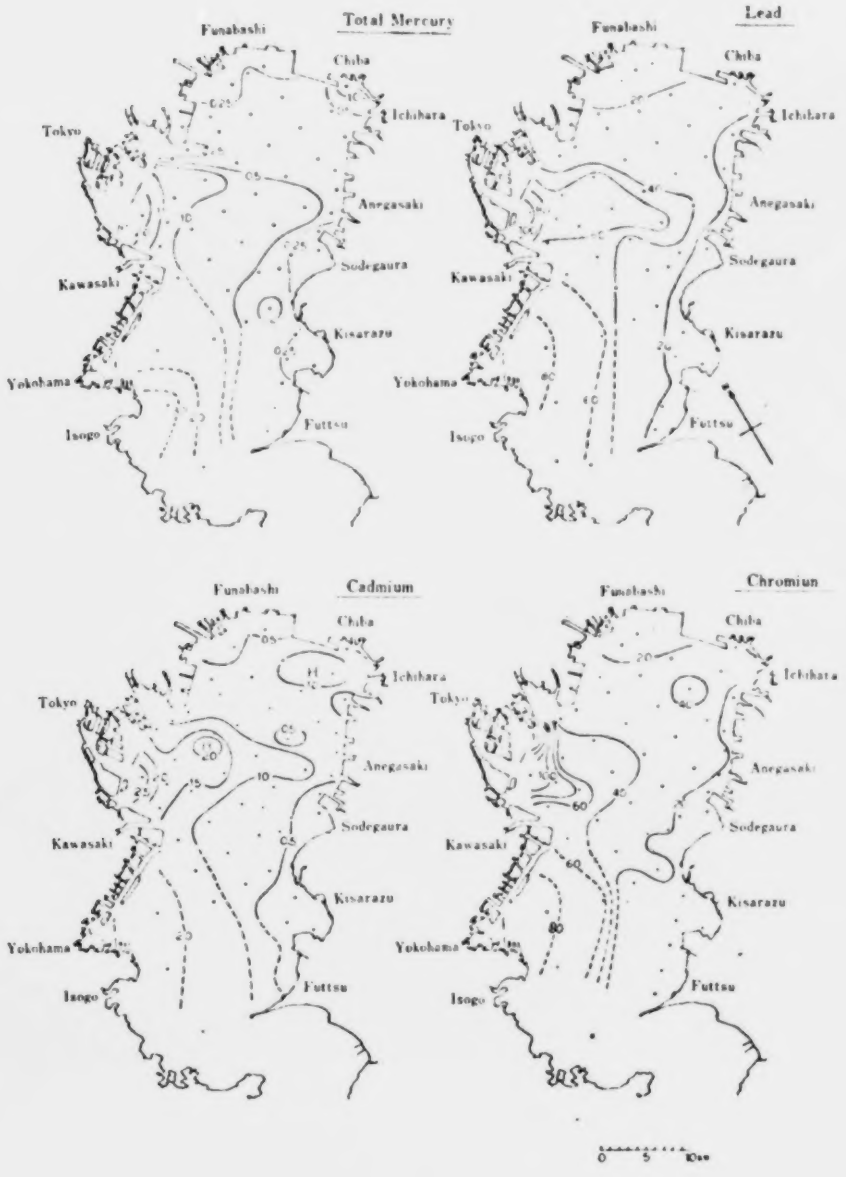


Figure 6 The Number of Species of Benthos in Tokyo Bay, Oct. 1971 (NO/0.125m^2)

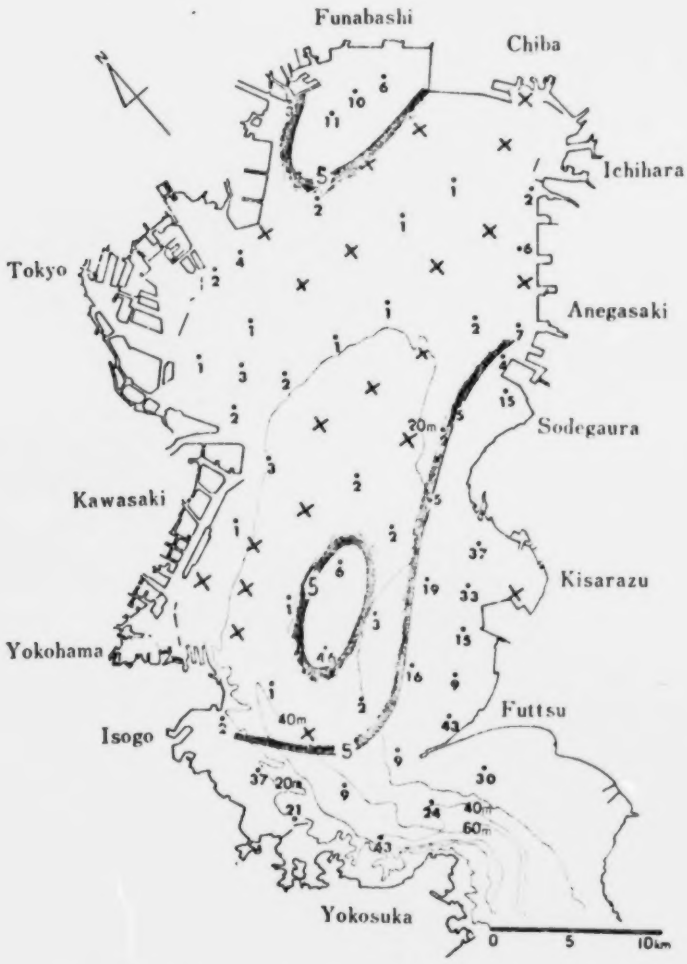


Table 3 The Seasonal Variations of Benthos of Tokyo Bay

	Number of points free from benthos	Number of species of benthos observed				
		Polychiata	Mollusca	Crustacea	Others	Total of species
May 1971 (15 points)	1	42	10	5	7	64
August 1971 (15 points)	7	45	2	4	6	57
October 1971 (72 points)	20	63	16	5	7	91
February 1972 (15 points)	1	47	12	8	9	76
Total 4 surveys (117 points)	24	71	19	11	11	112

mon off Isogo and in the bay mouth area, the plankton picture is a simple one.

Benthos: Table 3 shows the seasonal fluctuation in the types of life existing in the mud on the sea bottom and **Figure 6** shows distribution patterns of the number of types in October.

At almost a quarter of the survey points, no life forms were found, while Polychaeta make up over two-thirds of all types, so that pollution in the bay may be described as considerable.

As for the seasonal variation, the smallest amount of life is found in the stratification period while in the circulation period it is abundant. From Chiba-Ichihara to Kawasaki there is a belt which is entirely, or almost entirely void of organisms. From Sodegaura to Futtsuzaki, along the coast near Funabashi and around Nakanose organisms are fairly common. These distribution patterns correspond, to some degree, to ignition loss or COD. Compared with the total count of organisms for October, in areas where the ignition loss was more than 10%, less than 10 organisms were found. Again, as to the correlation with COD, in the case of over 20 mg O_2/g, the total number of organisms was less than 10. 10–20 mg O_2/g, the total number of organisms was 10–100 organisms. Less than 10 mg O_2/g, the total number of organisms was over 200 organisms. It is possible to see the above approximate relationship.

While it has become apparent that most parts of Tokyo Bay are almost void of living organisms, when a comparison is made with the results tabulated by Kitamori [3] who carried out a survey covering 61 places in October, 1967, it becomes evident that there has been a definite decrease in the number of areas in which numerous organisms are found. Whereas at that time there was a count of 80 organisms close to Tokyo, off Kawasaki and Yokohama, four years later the count is down to less than ten. Whereas the count near Anegasaki, Sodegaura and the Futtsu coast was over 80, it is now under 80, and areas with a count of over ten are decreasing in number. Hardly any change has been observed off Funabashi, and Kisarazu and at Nakanose.

4. Summary

(1) When the state of pollution of Tokyo Bay is expressed in terms of the alkali process-COD, the figure is about 1–3 mg O_2/*l* in the circulation period and close to 10 ppm in the stratification period. There is also considerable seasonal variation. Only survey results for October are available in the case of the acid process-COD and these show 1–8 mg O_2/*l* for surface water at 68 places, 65% of these being within the environmental quality standards and 1/3 exceeding them.

(2) Based on COD (the acid process) estimates, the total amount of

pollutants flowing into Tokyo Bay was about 1,100 tons per day.

(3) Electronic computer dispersion calculations based on the pollutant inflow results referred to in (2), above, showed high figures for the west and low figures for the east.

(4) The degree of saturation of dissolved oxygen in surface water fluctuated considerably, going as high as 180% in August and down to less than 50% in May. Near the sea bed in August it was under 20% in the northern half of the bay and in October, north of a line between Kawasaki and Funabashi, under 50% and north of a line between Kawasaki and Kisarazu it was under 75%.

(5) Readings for water transparency were quite low at 1–2 meters throughout the entire area. in May and August.

(6) The indicator of eutrophication, total nitrogen concentration, was high, readings over 0.8 mg N/l being obtained north of a line between Yokohama and Futtsu.

(7) Survey results for benthos showed seasonal fluctuations corresponding with water circulation, these life forms being found throughout almost the entire area from the circulation period to spring, but azoic areas being found from the stratification period into autumn. In August half, and in October about 1/4 of the areas surveyed were azoic places.

When these results are compared with those obtained in October, 1967, a remarkable drop in the organism count is seen in the coastal area from Yokohama to Kawasaki and it is seen that throughout the entire bay there has been a decrease in the number of places where large numbers of organisms are found.

(8) The decrease in benthos corresponds with the drop in quality of the sea bed and in most of the northern half of the bay ignition loss is over 8% and COD ratings over 10 mg O_2/g (dried mud).

(9) In October analyses were carried out at 68 points in connection with the eight items related to health in environmental quality standards, but nothing was detected. However, heavy metals, etc. were found in the sediments on the sea bed and the distribution pattern elucidated. The area in which the highest concentrations are found extends out from the Tokyo vicinity toward Anegasaki and along the western side of the bay. Concentrations in these two areas were quite high when compared with other parts of the bay.

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2) Hogetsu, K.: Presentations at the 3rd Symposium on Water Pollution by the Japan Research Group of Water Pollution, June 7, 1972.
3) Kitamori, R.: Report of Research Marine Pollution Prevention (Water Quality), Japan Assoc. for Preventing Marine Accidents, 1968.